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The Use of Smart Glasses for Lecture Comprehension by Deaf and Hard of Hearing Students

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Abstract
Deaf and hard of hearing students must constantly switch between several visual sources to gather all necessary information during a classroom lecture (e.g., instructor, slides, sign language interpreter or captioning). Using smart glasses, this research tested a potential means to reduce the effects of visual field switches, proposing that consolidating sources into a single display may improve lecture comprehension. Results showed no statistically significant comprehension improvements with the glasses, but interviews indicated that participants found it easier to follow the lecture with glasses and saw the potential for them in the classroom. Future work highlights priorities for smart glasses consideration and new research directions.

Author Keywords
Deaf; education; accessibility; American Sign Language (ASL); multimedia.

ACM Classification Keywords
H.5.m [**Information Interfaces and Presentation**]: Miscellaneous. K.4.2 [**Computers and Society**]: Social Issues – *Assistive technologies for persons with disabilities*.

Classroom Accessibility for DHH students

Figure 1: This image shows a mainstream computing class at RIT. Both hearing and DHH students attend the class. As shown, the professor is speaking the classroom lecture, using slides (on the right) as part of the presentation. An ASL interpreter (on the left) provides accessibility support for DHH students. © RIT.

Introduction

For deaf and hard-of-hearing (DHH) university students who attend classes with a hearing instructor and classmates, full access to lecture information can be difficult. Unlike hearing students who can get lecture information simultaneously from both auditory and visual channels, DHH students are limited to visual input. Typically, universities provide various accommodations for DHH students to make the spoken lectures visually accessible. During lectures, sign language interpreting and / or captioning may be provided. Note-takers are also common for providing written summaries of lectures.

As shown in Figure 1, a mainstream classroom lecture includes multiple sources of visual information for DHH students. Rather than serving as mutually reinforcing information, these multiple sources mean that DHH students must constantly shift their visual attention and focus. DHH students, typically seated in front rows for best viewing, must move their head and/or eyes from one physical location to another to switch between these sources. With this visual dispersion, information is often missed, causing the students to see only fragments of the lecture content from each source.

The switching is exacerbated when using sign language or captioning. In both cases, the accessibility support lags behind what the lecturer is saying due to the time needed to translate into sign language or type the captions. This lag typically causes the presentation (lecturer and slides) to get out of synch with the accommodation (sign language and/or captions).

Research has examined potential ways to minimize lost information due to attention switching and accommodation lag. In one study, researchers used monocular head-mounted displays to project ASL interpreting while students watched lectures [5]. Students talked about the challenge of trying to split their visual attention between the projection on the monocular display and the other information in the room. Other approaches to the problem of visual dispersion have included consolidating visual information sources onto one personal display [2], and controlling the pacing of classroom presentations to provide sufficient time for DHH to view both presentation and accommodation [1, 8, 9]. None of these options has, yet, demonstrated the comfort or comprehension improvement needed.

Consistent with the approach of consolidating visual information sources, in this research we examined whether eyewear technology might provide an effective means of reducing visual dispersion, enabling improved lecture comprehension. The present study goes beyond previous work by testing lecture comprehension with this consolidation and by using smart glasses that have the potential for flexibility and (with future generations of technology) natural viewing experience.

Pilot work

We began with pilot investigations to explore the potential for eyewear use in the classroom. Specifically, we were interested in whether the DHH students found the slides, American Sign Language (ASL), and captions intelligible using smart glasses. As shown in Figure 2, we began by testing with Google Glass. Our first step was to get informal feedback from DHH students at our CAIR lab [3] at RIT. With Glass,

Figure 2: Informal testing involved use of Google Glass. Note that video projection of ASL or captions is onto the Glass display in the upper right for users. ©RIT.

Figure 3. The EPSON Moverio BT-200, from [6].

the projection display is situated on upper right lens, requiring students to shift their eyes between visual sources. Students did not think this improved problems of visual dispersion. Therefore, for a more formal pilot, we switched devices to the EPSON Moverio BT-200 (Figure 3), which provides the display straight ahead, allowing viewing of both the projected information and the room without a physical shift.

For this pilot, either ASL or captions were projected onto the glasses while students watched the slides on a screen in the front of a classroom. We asked DHH summer students at the Rochester Institute of Technology (RIT) to provide comments about the intelligibility of these three sources. This pilot, and all other work reported here, were approved through the IRB at RIT.

Seven DHH RIT summer students viewed either ASL or captions projected onto the glasses while watching slides on a screen in the front of a classroom. Overall, the students thought that the Moverio eyewear was useful and reported a preference for ASL interpreting over captions in this experimental situation. They reported difficulty in understanding captions on the glasses display due to the limited number of words that could be displayed on the space.

In terms of the ASL, participants reported that it was difficult to clearly see the fingerspelling. This problem was likely exacerbated by a design decision to use a transparent ASL video on a white background. The students also expressed a desire to control some display characteristics.

We note that the students reported that the Moverio glasses were heavy and did not fit well. Acknowledging that this was a current technology limitation and one that would likely be improved upon as technology evolves, we decided to proceed with an experimental investigation of smart glasses for classroom use.

Our experimental study was designed to answer the question: Can lecture comprehension for DHH students be improved in mainstream classrooms by using smart glasses to limit difficulties caused by visual dispersion?

Experimental Methods

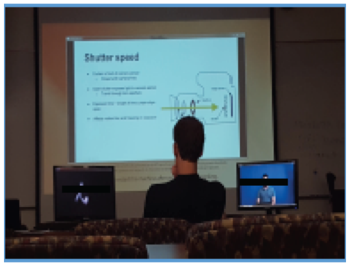
Our pilot work informed several aspects of the experiment: 1) choice of eyewear device, 2) testing with ASL only (no captions), 3) use of a dark background for the ASL, and 4) providing options for arrangement of the ASL interpreter on the display.

Development

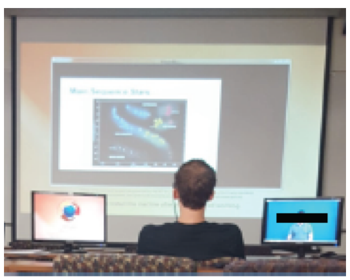
The pilot software was changed for the experiment such that participants had the choice of six viewing options for the *ASL interpretation* and *lecture presentation* on the glasses. In four of these, the video of the *ASL interpretation* was displayed at a half-screen height and participants selected which of the four corners was the anchor for the video. The ASL video occupied about ¼ of the display. In the remaining two, the ASL video was projected at a full screen height and could be anchored on either the left or the right side. The video occupied about ½ of the display. In all viewing conditions, the ASL was presented binocularly.

The transparent video was projected against a black background. In all cases, the part of the glasses that did not contain the black background was transparent

Figure 4: Experimental classroom setup



The participant perspective from classroom emulation in the “without glasses” condition. The lecturer is shown on the right-hand monitor; the ASL interpreter is on the left-hand monitor.



Third-party perspective from classroom emulation in the “with glasses” condition (the participant is wearing the smart glasses). The lecturer is shown on the right-hand monitor; there was no lecture content displayed on the left-hand monitor.

and participants could view the *lecture presentation* (slides or lecturer) by looking directly at the source.

The six viewing options were given at the start of the glasses portion of the experiment. Participants were given approximately 10 sec to adjust the glasses. A 1min 30sec video was then shown for the participants to see each of the six viewing options. After the video was shown, each participant was asked for their preferred viewing option. That preference was used throughout the experiment when showing the primary video. The majority of participants choose one of the larger ASL video options.

Experimental design

We used a within-subjects design with two conditions (with and without smart glasses) in which participants watched each lecture under both conditions. That is, they viewed the lecture presentation directly while having ASL interpretation displayed on the glasses (the ‘with glasses condition’) or on a computer monitor (the ‘without glasses’ condition). The order of presentation for conditions and lecture was counterbalanced to reduce effects due to learning.

There were three measures that tested lecture comprehension: 10 multiple choice questions, 4 transfer questions, and 6 retention questions.

Experimental setup

The experiment was designed to emulate a mainstream classroom environment, similar to what a DHH student would experience. As shown in Figure 4, participants sat in the front row of a classroom with the lecture slides projected straight ahead and two monitors on a table in front of them for displaying the lecturer and the ASL interpretation. Running Java code and VLC media player software to synchronize presentations, a PC projected simultaneous muted videos of the lecturer, slides and ASL interpreter.

The lecture materials were two short lectures (about 10 minutes each), one about the life cycle of stars (*Stars* lecture) and the other about *Photography*. The slides of both lectures contained text and figures. The video preparation followed the procedure adopted by Brandão et al. [1], in which all materials were recorded in unison: the instructor, interpreter and the instructor’s computer screen were simultaneously recorded / captured. At playback, all streams were synchronized to maintain the same time relationship as during recording. Thus, this playback situation recreated a typical mainstream classroom in which the interpreting lags slightly behind the spoken lecture.

Experimental session

Participants were individually tested in sessions lasting no more than one hour. Each session consisted of: 1) welcome and Informed Consent, 2) pre-lecture assessment of each participant’s familiarity with lecture concepts on a 5-point Likert scale, 3) determination of viewing preference, 4) one lecture followed by comprehension questions and interview, 5) other lecture followed by comprehension questions and interview, and 6) final semi-structured interview to gather information about participants’ experiences with the smart glasses. Participants were compensated $20.

Three hearing researchers were present for each session. One experimenter served both as a researcher and interpreter.

	With / Without Glasses conditions
Multiple choice (N = 15)	
	4.73 (1.62) 4.47 (1.85)
Transfer (N = 8/7)	
Stars lecture	2.25 (1.03) 1.71 (1.11)
Photography lecture	1.14 (.69) 1.50 (1.07)
Retention (N = 8/7)	
Stars lecture	3.00 (1.07) 2.29 (1.60)
Photography lecture	3.00 (1.55) 3.38 (.52)

Table 1: Means and standard deviations in the with / without glasses conditions for the three measures of lecture comprehension.

Participants

Participants were recruited through email and fliers across the RIT campus during the summer of 2016. Students who expressed interest in participating were asked to complete a screening questionnaire to determine eligibility: participants had to be at least 18 years old, be DHH, use ASL interpreting as a classroom accommodation, and have the ability to see short and long distances with or without correction. The Moverio eyewear could be worn over corrective glasses.

Our recruitment resulted in 15 participants: 12 identified as deaf/Deaf and 3 as hard of hearing. Three of the participants wore corrective eyeglasses. No participant had used the Moverio glasses previously.

Results

To determine whether the glasses improved lecture comprehension, scores from the multiple-choice comprehension test were first examined. The resulting scores (Table 1) were normally distributed. The paired t-test on these scores showed no significant difference between the 'with glasses' and 'without glasses' conditions ($p>.05$, two-tailed).

The independent t-tests on the transfer and retention comprehension measures (Table 1) also resulted in no significant differences between the two conditions ($p>.05$, two-tailed).

As a rough test to help assess whether any prior knowledge of the lecture content might have influenced performance on comprehension tests, we checked for any correlation between participants' Likert scale reports of knowledge about the content prior to the lecture with their performance on the comprehension test. The Spearman's rank correlation coefficients were not statistically significant for either the *Stars* lecture ($R = -.07$) or the *Photography* lecture ($R = .13$).

The interviews with participants were coded to determine the eyewear experience in this simulated classroom experience. Validating the motivation for this work, the most commonly stated feedback from the DHH participants was that without glasses they had to frequently shift their attention between different sources of information, often requiring the physical movement of their head. With the ASL interpretation binocularly projected onto the glasses, this visual dispersion was minimized. As one participant said: *"I watched the interpreter more. And I watched some of the slides, too, because it was easy to watch them at the same time. In real life, I have to move and miss stuff. With the glasses, it was easy to move and follow both."*

In terms of the usefulness of the eyewear, participants frequently commented that they could imagine the glasses being used in the classroom, reiterating that the glasses helped to minimize or facilitate shifts between visual sources. The potential for DHH students to do their own note-taking was raised: *"Yes, it is helpful because I liked that I could see the interpreter sign and look at the PowerPoint. If I need to take notes myself, then it is easier."*

There was little feedback about the interpreter positioning from these participants, suggesting that the issues in the ASL projection found in the pilot work had been addressed in the experimental study.

Consistent with the pilot work, the participants complained that the Moverio glasses were uncomfortable. Also, they often found themselves having to adjust the glasses position during a session as the glasses slipped / moved.

Discussion

In this research we asked whether having ASL interpretation available in the same visual field as lecture presentations would facilitate the comprehension of mainstream classroom lectures for DHH students. Results of the quantitative measures for comprehension showed no gains with the interpreter in the same visual field; nor were there decrements when using the glasses.

The qualitative results were more supportive of the potential of this idea. Specifically, participants frequently mentioned that the glasses, with the binocular presentation of lecture interpretation made the lectures easier to watch and minimized head shift.

We note limitations with the methods used here that likely influenced the comprehension results. Most noticeably, there were fewer participants than would have been ideal for this study. In addition, problems with the lectures themselves may have caused an underlying problem. The experimental lectures were each short and not fully representative of a university lecture.

It is important to mention that the specific eyewear used in this study was poorly rated by the participants in terms of comfort and fit. Their need to adjust the glasses placement within sessions, for example, may have distracted from any potential benefit.

Future work

Our research participants give us reason for optimism about this approach for improving classroom comprehension for DHH students. In future work, however, we suggest some design changes as well new use case scenarios. Most notably, we see the need to find more comfortable eyewear for this idea to be effective. Also, users of technology do not wish to look 'weird' [10]. In sum, choice of eyewear device is critical.

Given feedback from our pilot, we did not test the use of captions in this experiment. In the future, displays that allow projection of more text offer a real opportunity for captions in classroom lectures either in addition to [4] or instead of ASL [7]. Interestingly, several participants mentioned that using eyewear with the projection of ASL interpreting offered the potential opportunity for DHH students to take notes during lectures. This is something we would like to examine further.

For our controlled experimental testing, we simulated a classroom situation, having pre-recorded lectures, slides, and ASL interpretation videos. For more realistic testing, it would be useful to test this eyewear idea in a live setting.

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